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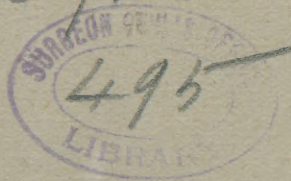
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THE IMPORTANCE OF
PHYSIOLOGICAL CHEMISTRY AS A PART
OF MEDICAL EDUCATION.*

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IN this age of progression, when the attention of the medical profession is being directed toward a broader and more comprehensive system of medical education, it is well to consider some of the claims presented by physiological chemistry to occupy a prominent place in the medical curriculum of the day, or, if not as an integral part of medical study itself, as a fundamental part of that preparatory training which all progressive minds in the medical profession consider as so important for the most complete and intelligent understanding of the science of medicine in its broadest sense.

There can be, I think, no objection from any quarter to the general statement that the study of biology, together with chemistry and physics, constitutes the best and most

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natural line of preparatory work for the medical student. Indeed, it may well be questioned whether physics, chemistry, and a certain amount of biology should not form a necessary part of the training of any person seeking a liberal education. To be sure, the intending medical student may well pursue these subjects much more thoroughly than one who desires general training rather than special knowledge. The biological sciences, however, so closely underlie the science of medicine, are so plainly the substructure on which the latter rests, that one can hardly conceive of a broad and intelligent comprehension of the subject without a preliminary training in some one or more of the biological sciences.

Just here, however, in order to prevent any possible misunderstanding, let me at once emphasize the fact that what is required first of all of a medical student, as well as of a student in any department of learning, is a broad and well-developed mind, trained to habits of thought and observation, endowed with the power of logical reasoning, and fully alive to the necessity for broad and liberal culture. This is obviously the first requisite, and it is folly to assume that a limited biological training, although valuable in itself, can counteract the defects or make good the deficiencies incidental to the lack of intellectual development. A boy fresh from the district school or from the high schools of our cities, with his mind mostly unformed, is fit neither for the study of medicine nor for that of any other profession. What he requires first of all is mental training. We need not discuss here whether such training should be obtained through classical studies or through mathematics and the natural sciences. It is sufficient for present purposes that the need for general training be widely recognized. Let it be understood that the medical profession demands men of high intellectual attainments, broad and

scholarly, and that there is no short road of preparation for medical studies, through biological or other channels, any more than for the professions of law, theology, art, or literature.

Granting all this, as every one interested in the future development of medicine must, we come back to our starting point—viz., that biology constitutes one of the most important, if not *the* important, preparatory study in medical education. Biology treats of the science of life, of the structure and function of living organisms high and low in the scale. What more natural and appropriate, therefore, than that the student aiming to make his life work the study and treatment of the diseased human body should turn to the study of animal and vegetable forms in order to gain knowledge and experience of the general laws regulating life in all its phases? It is only by a close scrutiny of the simpler forms of life that we obtain the requisite knowledge to unravel the complexities of structure and function characteristic of the more highly developed human organism. The broad line of demarcation formerly drawn between the life processes of animals and plants has been gradually growing narrower and more indistinct until to-day we are forced to believe in the existence of essentially the same kind of protoplasm (*i. e.*, containing essentially the same chemical substances) in animal and vegetable cells alike, and without regard to the position they occupy in the scale of life, whether in man or in the highest or lowest animals and plants. This naturally leads to the view “that definite fundamental chemical formations and changes are common to all living beings”; and although there are many superficial as well as fundamental differences between the different classes and orders of animals and plants, yet it is evident “that many processes can take place according to a conformable fundamental type.

Further in the life processes of man these parallels are again found, whose simplest manifestation we perhaps follow with the least difficulty in the lowest organisms. We are thus brought to a definite unity in the original structure and processes of living existence." * "All living beings, of form and life-phenomena the most widely different, appear to owe their fundamental structure to an original chemical organization, with properties common to them all," from which we can see direct gain to the medical student in the study of lower forms of animal and vegetable life.

Further, as an indirect gain, it must not be overlooked that in such lines of biological inquiry the student, while acquiring a fund of useful information more or less directly applicable to his every-day needs, undergoes a training the value of which can not be overestimated. His powers of observation are called into play, the habit of drawing deductions from observed facts, the noting of resemblances and differences, all tend to educate him in methods of exact work and lead eventually to habits of self-reliance and a freedom from prejudice and preconceived opinions which will prove of inestimable value in his after-life of practice by the bedside. He learns to appreciate the significance of small things, and becomes thereby well trained in the essentials of accurate diagnosis in a manner which can not be imitated by text-book instruction in any branch of knowledge. He must be taught to observe, and to observe accurately; and being possessed of reasoning powers, soon acquires the habit of close and logical reasoning.

All this, I take it, will be readily granted by the unprejudiced mind, but the question naturally presents itself here

* Quotations from Hoppe-Seyler's address on the Development of Physiological Chemistry and its Significance in Medicine.

as to what is meant by or included under the term of biology. We need not stop for a scientific definition of biology, for our interest centers rather in the interpretation of the word as applied to biological courses of instruction. Judging from the courses offered by most of our institutions of learning under the head of biology, the latter ordinarily includes more or less zoology and botany, with a comparatively large amount of dissection of typical forms. This is coupled with a certain amount of histology and perhaps embryology, all being intended to constitute a more or less thorough presentation of the morphological side of biology. Less thoroughly presented, ordinarily, is the physiological side. To be sure, physiology is usually found as a part of the curriculum of a biological course, but seldom is it taught other than by text-book or with that degree of thoroughness characteristic of morphological instruction. Further, in those institutions where physiology is given a prominent place in the biological course, it is usually a one-sided presentation of the subject. It consists mostly of muscle and nerve physiology, with demonstrations of blood pressure and kindred experiments designed to illustrate mainly the mechanical side of physiology. I would not be considered for one moment as saying a single word against such lines of physiological experimentation or instruction; it is certainly of the highest importance and, in my judgment, is just what is needed in every course of physiological study. But what I would like to impress upon my hearers is that there is another side of physiology which, in this country at least, has not been cultivated as I believe it should be—viz., the chemical side of physiology, or physiological chemistry. It deals with quite a different series of problems from those pertaining to so-called pure physiology, but I venture to say that the phases of physiological study and investigation it presents

to us are as fundamental, if not more so, than any other single line of physiological work.

By physiological chemistry I mean something more than the mere application of chemical analysis to a determination of composition. This, to be sure, is important, but more valuable still is a proper understanding of the processes or lines of functional activity going on in the organs and fluids of the body, a rightful interpretation of which, however, must depend greatly upon our knowledge of the composition of the various parts of the body, and upon the chemical constitution of the many organic substances disseminated through the organism. Physiological function depends largely, if not wholly, upon chemical nature and constitution, and although there is much that is vague and incomplete in our knowledge of the chemistry of the body, it is very evident that such chemical information as is obtainable is a necessary preliminary to all physiological study. Indeed, there is hardly a question either in physiology or in the science or practice of medicine that does not draw to a greater or less extent upon physiological chemistry for its solution. As I am now addressing a body of physicians rather than physiologists, I can not do better than to repeat a remark of Professor Hoppe-Seyler's, taken from an address on the development of physiological chemistry, as illustrative of the important position this well-known authority considers this branch of chemistry should occupy in the medical curriculum. "I can not understand," he states, "how at the present day a physician can recognize, follow in their course, and suitably treat diseases of the stomach and alimentary tract, of the blood, liver, kidneys, and urinary passages, and the different forms of poisoning—how he can suitably regulate the diet in these and in constitutional diseases—without knowledge of the methods of physiological chemistry and of its decisions

on questions offering themselves for solution, and without practical training in their application." Again, Leube, the noted clinician, exclaims against the underestimation of physiological chemistry in medicine, and emphasizes the probability that the future success of medicine is dependent mainly upon the advancement of this branch of chemistry. In every medical school in the land there should be a well-appointed laboratory for the practice and study of physiological chemistry in every direction bearing on medical science. So, too, in every well-rounded biological course there should be ample facilities for instruction and experimentation, not only in pure physiology, but likewise in physiological chemistry, so that a broader and clearer conception of physiology may be obtained than is possible by the presentation of a single side of the subject.

Obviously, in a course of biological instruction, the morphological side rightly receives the first attention; form and structure must be first studied, and thoroughly studied, but chemical composition and function are not to be entirely ignored. So, too, in medicine; the unsymmetrical development, especially of the last twenty years, by which the sovereignty of morphology has been attained, giving undue weight to anatomical methods of investigation, has reached its climax, and the clinicians even are now looking to physiological chemistry to aid them in unraveling many of the hidden processes of life, thus hoping to gain clews to clearer methods of diagnosis and more rational lines of treatment. And yet our medical schools are sadly lacking in facilities for teaching, as it should be taught, this important branch of science. Contrast, for example, the time allotted and the facilities afforded for studying physiological chemistry with the time and facilities given to anatomy, histology, and pathology. The difference is appalling, and I say it with all due respect to the position these three sub-

jects justly occupy in the medical curriculum, and with, I think, a due appreciation of the great gain accruing to medicine from the marvelous development of pathological investigation which has been witnessed during the last two decades. If, however, a small fraction of the time and energy given to these branches of medicine had been devoted to the simultaneous study and investigation of the chemical processes of the body in health and disease, I am sure equally important results would have been obtained, and, as a final outcome, a far more satisfactory explanation of many phenomena for which anatomy, histology, and pathology alone have thus far given only incomplete or unsatisfactory explanations. It is from a judicious combination of the results obtainable by different lines of inquiry that the broadest and most definite, as well as the most accurate, deductions are to be drawn. From the very nature of things, no one branch of biology, no one branch of medicine, is capable of affording as complete and satisfactory answers to the many general questions constantly arising as can be furnished by broader and more comprehensive methods of work.

Let us consider now for a moment some of the reasons for our belief that physiology and medicine are greatly indebted to physiological chemistry for their advancement. Obviously, in the first place, we must remember that our knowledge of the composition of the tissues, organs, and fluids of the organism, whether animal or vegetable, is derived entirely from chemical study and investigation. This is plainly self-evident; but, when we consider how far-reaching are the facts thus obtained in promoting our understanding of the laws of growth of the human body, of the relationships of the various physiologically active and inactive tissues, of their development, of the character and extent of their activity, and of all the variations inci-

dental to pathological conditions, we see at once the great importance of this knowledge in aiding us to a rightful interpretation of physiological laws.

The great progress made of late years in our knowledge of the various digestive juices of the body, of their mode of action, of the character of the products resulting from the digestion of the various classes of foodstuffs, of the conditions favorable and unfavorable to ferment action—these and many other things connected with the study of digestion in its broadest sense have all been accomplished as the result of long-continued and laborious experimentation in the domain of physiological chemistry—results that have not only helped to give us broader and clearer ideas of the physiology of digestion, but have made possible much of the advance in the diagnosis and treatment of disorders of the alimentary tract.

Take from us our knowledge of the chemical composition of muscle and nerve tissue, and of the characteristics of the various substances entering into their structure, and what a blank would remain! Consider the importance of our ever-growing knowledge regarding the chemical changes going on in the two master tissues of the body, with their influence on heat production and on proteid and other forms of metabolism, and remember at the same time that, in spite of all that has been accomplished in the past, we have hardly passed the threshold of the possibilities opening up before us.

Then, too, the whole broad question of nutrition in general, with its bearing on health and disease; the study of the urine and fæces, with the rich results such study affords as a means of diagnosis; the study of the liver and its secretion, the bile—all are in great part chemical problems, partial solution of which has already afforded results of inestimable value.

Then consider for a moment the part chemistry has played in bringing about our present understanding of the manner in which micro-organisms act in the animal body with its bearing upon the whole question of infectious diseases, the discovery of the production of distinct chemical poisons by specific pathogenic bacteria, with the impetus this fact has given to the search for methods of producing immunity. Then, too, we must not forget to recall the great aid chemistry has lent to therapeutics, not only giving us methods for the preparation of purer and more definite products, but opening up methods of studying the physiological action of drugs which have greatly advanced the growth of scientific pharmacology.

In the brief time allotted for this paper we can not, however, even mention further specific instances of the way in which physiological chemistry touches and strengthens almost every department of medicine. I would that I had time to sketch for you a more detailed picture of this whole matter as it presents itself to my own mind, for I am sure that by so doing it would be possible to impress you more fully with the great need of broader and more liberal methods of instruction in this department of science, both as an aid to a better interpretation of biological laws and as a necessary part of a *liberal* medical education.

And now allow me to say a word regarding the methods of instruction in physiological chemistry. Happily, the day is past when a medical student is compelled to obtain his knowledge of medicine from lectures or even from books alone. Personal instruction and personal experience in the laboratory are essential requisites in any course of instruction that aims at the highest and best results. So in physiological chemistry there must be a well-equipped laboratory where each student is provided with the neces-

sary space and outfit for demonstrating the fundamental truths of chemical physiology. Instructors, too, must be provided, so that at the most not more than fifteen men shall be under the guidance of one teacher, who shall thereby have time and opportunity to study and develop the material committed to his charge to the fullest extent; for men's minds, as you well know, are not all constructed on the same plan, and personal idiosyncrasies need to be recognized and dealt with in such a manner that each may receive the full benefit of the knowledge and training provided.

A course in physiological chemistry, worthy of the name, should extend at least through six months and preferably through a whole year, with an average of fifteen hours of laboratory work a week, interspersed with lectures, recitations, and demonstrations. Such a course of instruction as I have in mind can be advantageously taken only by men who already have knowledge of general, analytical, and organic chemistry, physics, anatomy, and histology, together with more or less familiarity with general physiology. You say, perhaps, that no medical student can afford to spend such an amount of time on a subject only indirectly connected with medicine. But I believe that to be a grave mistake—one that is in part responsible for the large numbers of half-educated men in the medical profession. As Dr. Billings, in a recent paper in the *Forum* on *Medicine as a Career*, has well said, "this country is in no need of men possessing the diploma of doctor of medicine; it already has at least twenty thousand more of them than it requires or can properly support; but it does need several hundred, say a thousand, more of properly trained physicians." Eighteen years of experience in a large university in teaching physiological chemistry as a part of a biological course, having for its chief aim the preparation of young men for the study of medicine, has convinced me

that the time spent in such study is well spent, and that such a line of work can be advantageously made a part of the university or college curriculum, so that the intending medical student may have a fundamental idea of the scope and aim of physiological chemistry before he enters upon his medical course proper, just as he has, or should have, a knowledge of comparative anatomy, physiology, and general biology.

But the medical school itself can well afford to establish a thorough course in this subject; indeed, no medical school at the present day can afford to be without such a course of study if it hopes to rank with the leading institutions of the land, or aims to provide instruction of the highest and fullest type.

And now just a word or two regarding the character of a course in physiological chemistry. There may obviously be different views upon this subject. I can simply present my own. First, I believe that the student should be taught, in the laboratory of course, the general reactions and properties of the various albuminous or proteid bodies, studying likewise their more common decomposition products, their relationships and chemical constitution so far as known. Next in order come the various forms of epithelial and connective tissue, the student separating for himself and studying the various albuminoids which give character to the respective tissues, as the collagen of white fibrous tissue and the gelatin derived from it, the elastin of yellow elastic tissue, the so-called chondrin from cartilage, together with mucin and nucleo-albumin from the mucous tissues. Adipose tissue naturally comes next, and the several fatty acids are separated and studied, melting points determined, and the differences between the natural fats noted. This preliminary work, which involves much more chemistry than can be readily indicated by this short

description, is followed by a study of the more important muscle tissue; the properties of muscle, plasma, and muscle-serum are noted and the various proteids and crystalline extractives characteristic of this tissue are prepared and examined. Myosin, the proteid of muscle clot, is especially studied and its resemblance to the related globulins of blood plasma noted.

Again, it must not be forgotten that in order to make such a course as I am outlining of the highest value, no opportunity should be lost to show the physiological bearing of all the results obtained; to try and instill into the mind of the student the idea that the facts of physiological chemistry have a wide application. Thus in the chemical study of muscle tissue, for example, many lectures and recitations may properly be interspersed; sections, for instance, from Foster's *Physiology*, making an admirable addition to the laboratory work, the object being to teach the student to make use of physiological chemistry as a means toward a broader and more accurate conception of physiological phenomena.

Muscle tissue is followed by a study of nerve tissue, the various bodies especially characteristic of this tissue, such as lecithin, myelin, cerebrin, protagon, and cholesterin, being separated and their general properties and reactions ascertained. The chemical differences between the gray and white matter are also noted, the neuroglia, neurokeratin, and brain proteids are studied, while chemical and anatomical relationships are compared in this as in all other tissues examined.

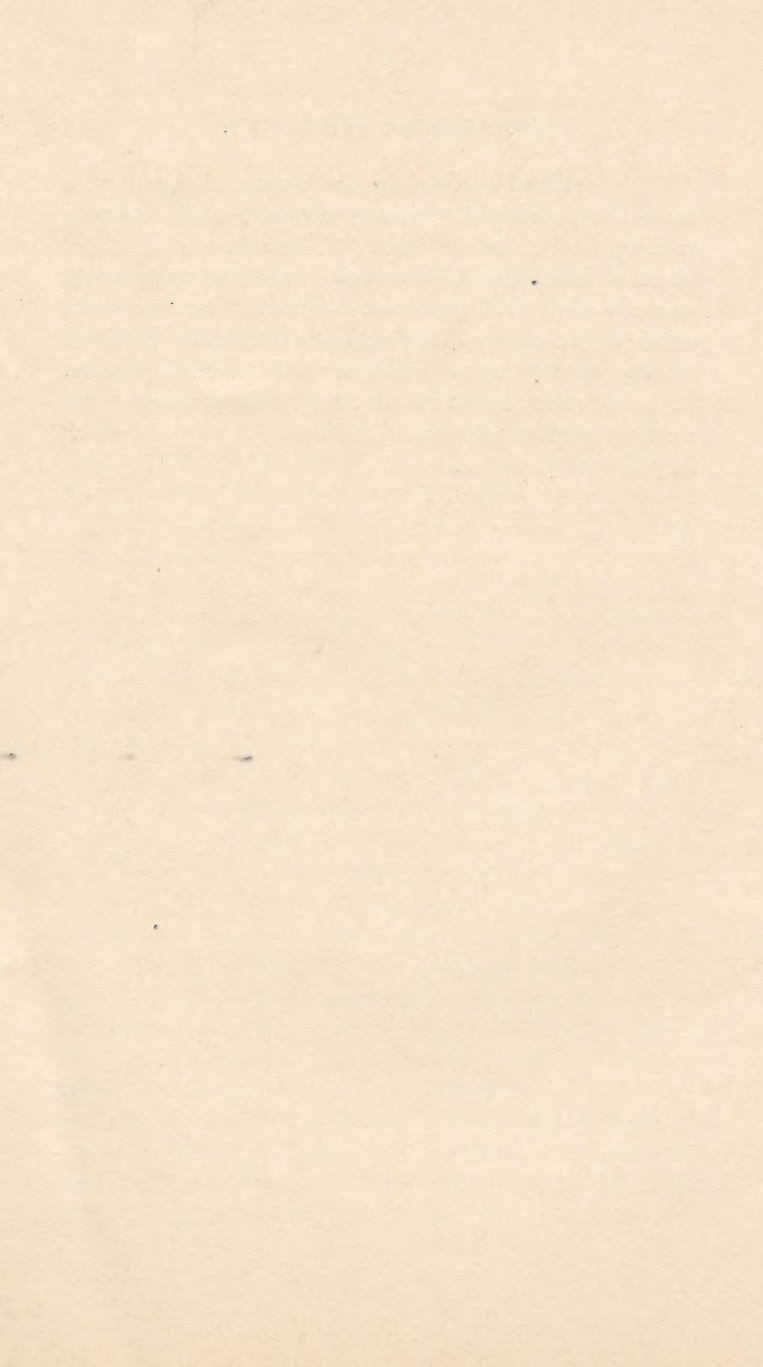
The study of digestion is taken up next, the various secretions—salivary, gastric, pancreatic, and intestinal—being thoroughly examined. Artificial digestive juices are prepared and their action on the various classes of foodstuffs noted and compared, this serving likewise to illustrate the

general action of enzymes or soluble ferments in distinction from the organized ferments. The many products of amylolytic and proteolytic digestion are prepared and separated, their chemical and physiological properties ascertained, and a thorough study made of both the chemical and physiological side of digestion in its broadest sense, it being the writer's custom at this point to have the students study and recite, in connection with their laboratory work, nearly all of Book Second of Foster's *Physiology*, which treats especially of the tissues of chemical action with their respective mechanisms and of nutrition in general.

In a similar manner, the liver with its secretion, the bile, glycogen and glycogenesis, the spleen, blood, milk, and urine are all studied, and the proximate principles giving character to the several organs and secretions separated and examined. Further, the metabolic activity of the hepatic cells and likewise of the kidney cells is demonstrated by appropriate tests, such as the synthetical production of hippuric acid through the agency of the cells of the *tubuli uriniferi*. The chemical changes incidental to respiration are also experimentally studied, and the detection of blood stains by spectroscopic and other methods duly considered.

To the urine special attention is given, students being taught not only to make examinations of this important excretion, but likewise to determine quantitatively the urea, uric acid, phosphates, chlorine, sulphates, combined sulphuric acid, hippuric acid, creatinin, indican, sugar, albumin, and other abnormal constituents. Further, by daily quantitative examinations of the twenty-four-hours urine, opportunity is given to demonstrate many of the truths of nutrition or general metabolism, such as the influence of various forms of diet on the excretion of urea, uric acid, phosphoric acid, and combined sulphuric acid, the influence of drugs on proteid metabolism, etc.

This outlines very briefly the general character of a course in physiological chemistry such as I would see open to every student of medicine. To one interested in this phase of physiological work such a course of study would naturally serve as a preliminary to more advanced work, which might readily deal with many interesting problems bearing directly upon medicine and medical practice. There is, in fact, almost no limit to the many questions constantly arising that demand the aid of physiological chemistry for their solution.



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FRANK P. FOSTER, M.D.

THE PHYSICIAN who would keep abreast with the advances in medical science must read a *live* weekly medical journal, in which scientific facts are presented in a clear manner; one for which the articles are written by men of learning, and by those who are good and accurate observers; a journal that is stripped of every feature irrelevant to medical science, and gives evidence of being carefully and conscientiously edited; one that bears upon every page the stamp of desire to elevate the standard of the profession of medicine. Such a journal fulfills its mission—that of educator—to the highest degree, for not only does it inform its readers of all that is new in theory and practice, but, by means of its correct editing, instructs them in the very important yet much-neglected art of expressing their thoughts and ideas in a clear and correct manner. Too much stress can not be laid upon this feature, so utterly ignored by the “average” medical periodical.

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